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HISTORY OF GUN-TYPE BOMBS AND WARHEADS (u)

Mks 8, 10 and 11 (u) Title unclassified per Susan Stinchcomb 4/18/2002

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SECRET

THE TX-8 BOMB

Mk 8 Exterior View

(b)(1), (b)(3)

LENGTH—116 IN
DIAMETER—14.5 IN.
WEIGHT—3150 LBS

Mk 8 Cross Section

12/8/50	TX-G Steering Committee appointed and holds initial meeting.
1/26/51	
	(b)(3)
3/15/51	
Early 1951	Externally carried TX-8 Bomb assigned nomenclature of TX-8 Prime.
10/51	TX-8 Prime program divided into two parts: TX-8-X1 (to cover carriage at subsonic speeds) and TX-8-X2 (a program to reduce drag in high-speed carriage).
11/51	Mk 8 Mod 0 achieves production.
1/52	Mk 8 Mod 0 enters stockpile.
4/1/52	(b)(3)
9/53	Mk 8 Bomb with Mk 8 Mod 1 Fuze (TX-8-X2) enters stockpile.
11/55	Mk 8 Mod 3 Bomb enters stockpile.
5/57	Mk 8 Bombs retired as Mk 11 enters stockpile.

<u>Mk 8 Warhead</u>

3/50	Gun-type warheads considered for missile application.
9/13/50	Santa Fe Operations Office requests that penetrating warheads be applied to guided missiles.
2/14/51	Santa Fe Operations Office authorizes design of XW-8/REGULUS.
1/18/52	XW-5/REGULUS program assigned priority over XW-8/REGULUS.
8/21/52	Field Command forwards proposed military characteristics for XW-8/REGULUS to Sandia.
9/24/53	Successful XW-8/REGULUS system test held.

8/54 Design of XW-8/REGULUS completed.

5/20/55 Program activity suspended.

TX-10 Weapon

5/6/48 Sandia Research and Development Board assigns priorities to weapon design projects.

1/21/49 Division of Military Application requests Bureau of Ordnance to study possible adaptation of Mk 8 as a light air-burst weapon.

4/22/49 Military Liaison Committee requests that study be restricted to a preliminary investigation.

3/8/50 Guided-missile symposium at Sandia Base proposes use of a lightweight gun-type device as a missile warhead.

7/6/50 Military Liaison Committee releases formal requirement for an air-burst, gun-type warhead.

8/9/50 Military Liaison Committee establishes formal requirement for a lightweight air-burst bomb.

8/17/50 Division of Military Application forwards characteristics for lightweight air-burst bombs.

9/6/50 Bureau of Ordnance, in reply to January 21, 1949 request of the Division of Military Application, offers to adapt the Mk 8 as a lightweight air-burst bomb.

10/3/50 Division of Military Application notifies Bureau of Ordnance that Sandia will develop the lightweight air-burst bomb.

10/18/50 Sandia Weapons Development Board discusses bomb and warhead applications. Santa Fe Operations Office subsequently authorizes deletion of warhead requirement. Bomb officially designated the TX-10.

4/1/55 Mk 11 design released.

1/1/56 Early production units of Mk 11 (Mk 91 Mod 0) become available.

7/1/56 Mk 91 Mod 0 enters stockpile.

8/56

(b)(3)

History of Gun-Type Bombs and Warheads

Mk 8 Bomb

The gun method of assembling nuclear material, used in the wartime Little Boy design, was the first atomic weapon system to be devised, predating the establishment of the Los Alamos Laboratory. The method was nuclearly inefficient and was largely ignored for a time after the end of World War II, while interest centered on implosion techniques.

(b)(1), (b)(3)

At this time, the Los Alamos Scientific Laboratory was fully occupied in the above-mentioned study of improvements in implosion devices, and suggested that the task of developing a water-penetrating weapon (which probably would use gun techniques) could best be accomplished by a military group. No immediate action was taken on this suggestion, but the subject was briefly examined by the Z Division of Los Alamos in late 1946 and early 1947.

(b)(1), (b)(3)

The topic was subsequently discussed in a meeting of the Weapons Subcommittee of the AEC General Advisory Committee, and a decision made May 15, 1947 that consideration of a penetrating weapon be postponed.[4]

Meanwhile, however, the Military Liaison Committee had been discussing the general subject of subsurface atomic weapons. At the instigation of the Navy member, Rear Admiral William S. Parsons (who had armed the wartime gun-type Little Boy for its historic drop on Hiroshima), Section ReM of the Navy's Bureau of Ordnance, prepared preliminary sketches of a penetrating gun device.

At about the same time, other groups were considering the same subject. The Joint Research and Development Board had established a Committee on Atomic Energy, and the subject of penetrating weapons was discussed in the October 2, 1947 meeting of this Committee. It was urged that serious consideration be given to the development of a gun-type device suitable for penetration use. Since the AEC weapon laboratories were already fully occupied with other high-priority work, the Committee recommended that the facilities of the Bureau of Ordnance be used.[5]

The Division of Military Application had also been considering the advisability of invoking the assistance of the military services in the development of penetrating weapons. Los Alamos had noted that gun systems were inherently inefficient, and expressed an opinion that the weapons laboratories should continue to concentrate on design of implosion devices.[6] Thus the Military Liaison Committee was requested to assign mechanical design of a gun-type penetration weapon to the Bureau of Ordnance.[7]

These several requests, all in the same vein, were presented for consideration to the Military Liaison Committee which, April 9, 1948, requested the Atomic Energy Commission to undertake development of a penetrating-type weapon, using the facilities of the Bureau of Ordnance.[8] This request was formally presented to the Bureau April 27, 1948, and accepted.[9] A code name of "Minnie" was initially assigned to the project, but was later found to have been used for a Bureau of Ships propulsion project and, in mid-July 1948, the name was changed to "LC" (a follow-on term to "LB," for the Little Boy), and which came to be commonly written as "Elsie."[10] That the Elsie program was considered a matter of some interest to the Military was indicated in a May 6, 1948 meeting of the Sandia Research and Development Board in which the project was assigned top priority, second only to the schedule for getting the Mk 4 Bomb into full-scale production.

The Bureau of Ordnance issued detailed work assignments. The Naval Ordnance Laboratory would be responsible for developing suitable pyrotechnic delay fuzes.

The Naval Ordnance Test Station would study external ballistics and design the tail. The Naval Powder Factory would investigate powder development. The Naval Ordnance Plant would handle much of the manufacturing and testing program, and when this location was subsequently closed, the work would be transferred to the Naval Proving Grounds and the Naval Gun Factory. Section ReM of the Bureau of Ordnance would provide overall design controls, including the task of guaranteeing survival of the nuclear assembly under impact conditions.

The development program would proceed in three overlapping phases. Feasibility and preliminary design studies would outline the most promising general design characteristics of the weapon, and these were scheduled for completion January 1, 1949. The second phase, covering experimental development and testing of prototype weapon design, would be completed a year later. The third phase, manufacture of prototype weapons, would be finished in another year, or January 1, 1951.

(b)(3)

The studies advanced rapidly and, by September 3, 1948, the Bureau of Ordnance could report that the design appeared feasible and that a weapon could probably be devised that would function satisfactorily after impact on water, and possibly after impact on hard surfaces which the weapon might encounter beneath the surface of the water.[11] It was initially felt that the fuze should be actuated at impact and have a delay of 1 to 2 minutes before bomb detonation, but it was later decided that a more reliable bomb would be created if the fuze action were initiated at time of release of the bomb from the carrying aircraft.

The diameter of the bomb would be about 14 inches and the weight would be about 3000 pounds, as compared to 28 inches and 8900 pounds for the Little Boy. These reductions were due to the more compact nuclear assembly and a decrease in the thickness of the bomb case. The shape would be roughly cylindrical, with a flat nose for good penetration characteristics, and the bomb would attain a maximum impact velocity of 1500 feet per second. The minimum release altitude would be 500 feet, to give the bomb enough time during its fall to assume proper entry attitude, and there would be no restriction on maximum release altitude. It was felt that three separate and independent fuzes should be used, to provide adequate reliability. A meeting was held October 25 and 26, 1948, with Los Alamos assuming the task of developing impact-resistant initiators.[12]

An extensive series of tests was performed. The first group included 174 half-scale bombs of 6.25-inch diameter. These were fabricated in 49 different configurations, and were impacted against targets of steel and concrete at different angles, striking velocities, and missile temperatures ranging from -65°F to +165°F.

(b)(3)

Following the above, some 38 full-scale impact tests were conducted, to confirm the half-scale results. Interior ballistic tests were performed, to check the burning rate of various propellants and the behavior of the missile in the gun barrel. As fuze components became available, they were subjected to the shock produced by firing from a 14.25-inch-diameter railway gun.

Two series of wind-tunnel tests were held, one at the University of Minnesota to obtain aerodynamic coefficients of various tail configurations, and the other at the California Institute of Technology Cooperative Wind Tunnel to evaluate aerodynamic characteristics of five basic designs.

directive was issued August 30, 1950, accompanied by a request that the facilities of the Bureau of Ordnance be used to the fullest extent possible.[17] At this time, the Elsie was assigned nomenclature of TX-8.[18]

An intensive study had been undertaken of changes required to allow external carriage of the TX-8. There were several reasons why these changes were necessary. For one, the fuze system had been designed to operate under protected bomb-bay conditions. For another, the shape of the TX-8, with its blunt nose, caused excessive drag, especially at high speeds.

(b)(3)

[redacted] It was obvious that this would require considerable study, and it was suggested that the Bureau of Ordnance establish a parallel program for the development of a Mk II Elsie suitable for either internal or external suspension, while work continued on an internally carried TX-8.[19]

The Bureau made a survey and reported that the existing shape of the TX-8 was adequate for subsonic external carriage if some minor changes were made to the tail design,[20] and the shape could be carried in the space available under the centerline of the F4U, AD and A2D airplanes. It was noted that development of a shape for external carriage at supersonic velocities would require additional study and development, and this effort would be of interest in connection with a recent proposal that an XW-8 Warhead be fitted to a guided missile. Subsequently, October 3, 1950, the Division of Military Application authorized development of an externally carried TX-8 with subsonic aircraft and development of a new bomb (the TX-11) for high-speed external carriage.[21]

Meanwhile, the Armed Forces Special Weapons Project had been drawing up a paper specifying the desired military and technical characteristics of penetrating-type weapons. [redacted]

(b)(1), (b)(3)

This paper was circulated for comment to Sandia and Los Alamos as well as the Military, and was subjected to a critical review.[23] The formal issue of the characteristics on November 10, 1950, however, retained the release speed requirement and noted that the bomb should function reliably when released at any altitude up to 50,000 feet and survive impacts on water, reinforced concrete, and--hopefully--thin steel plate.

(b)(3)

The November 22, 1950 meeting of the Sandia Weapons Development Board reviewed the overall gun-type weapons program, which now included the TX-9, TX-10, and TX-11, in addition to the TX-8. It was noted that the TX-8 was composed of three main parts: The nose, the tail, and the clamping ring which joined them. The bomb diameter had been fixed at 14.5 inches, its length at 116 inches, and its weight at 3260 pounds. The nose was a heavy forging with a blunt shape for water and ground entry, and contained the internal gun barrel, tamper, and projectile.

(b)(3)

A saddle on the external top of the bomb case contained switches and electrical connections to operate the primers.[25]

Sandia had proposed that an interlaboratory gun-type weapon coordination committee be established, similar in scope and authority to the TX-5 Steering Committee. Action was taken on this suggestion in late 1950, and the first meeting of this Gun Committee, with representation from Los Alamos and Sandia, was held December 8, 1950.[26] At this time, the TX-5 Steering Committee was renamed the TX-N Steering Committee to reflect its interest in all implosion weapons, and the new Gun Committee came to be known as the TX-G Steering Committee.

The first meeting of the TX-G Committee heard a report from Los Alamos concerning progress on design of an initiator for the TX-8. The initial design had been based on the device used in the Little Boy, and was then modified as design weaknesses were uncovered by the testing program. Some idea of the problems encountered were shown by the increasing impact requirements as the design progressed. The initial assumption had been that the highest shock encountered in ground impact would be 7500 g's. This figure had progressively increased during design and was now 100,000 to 300,000 g's.

(b)(3)

Studies were meanwhile in progress on systems for nuclear safing.

(b)(3)

In early 1951 it was decided to identify the adaptation of the TX-8 for external carriage at subsonic speeds as the TX-8' (or TX-8 Prime) program. Plans were made to make only minor changes to the TX-8 and provide early, but only partial, satisfaction of the requirements for an externally carried TX-8. It was felt that, if this program could not be accomplished within a short time, it should be canceled in favor of the TX-11 Bomb, then being designed for external carriage on high-speed aircraft.

At this time, the AD4 and the F4U5 were the only carriers specified for the TX-8'. The AD4 was selected as the test aircraft, and Sandia issued a contract through the Bureau of Aeronautics to Douglas Aircraft Company to modify this aircraft for TX-8 carriage. Douglas designed a nose cap to reduce drag and help protect the TX-8' fuzing elements.

In late October 1951, the TX-8' program was divided into two parts; the TX-8-X1 and TX-8-X2. The X1 was the basic TX-8' program; the X2 was to provide a cleaner aerodynamic design and reduce the drag caused by the saddle. Inasmuch as 20 drops had already been made with the TX-8-X1, its compatibility and reliability were felt to have been proven, and attention was concentrated on the TX-8-X2 design.[33]

The T-28 saddle functions were replaced by a small box located in the aircraft fuselage. This allowed the use of a standard two-hook bomb rack and increased the clearance between the externally carried bomb and the ground. Fairings were installed over the side fuzes to reduce drag. Fuze tapes used for safing were pulled through the nose fairing to protect them from the windstream. A quick disconnect was installed, to permit the weapon to be dropped with tapes in place, thus leaving barriers in the path between the primer and the propellant, and preventing the fuzes from firing the main propellant charge.

This new device was called the T-31, and a subcontract was issued for its development. Due to the subsequent failure of the subcontractor to achieve a satisfactory T-31, Sandia produced a design having the T-31 located inside the bomb pylon, thus making it possible to detach the arming tapes from the pylon after bomb release, and prevent aircraft damage caused by whipping of the tapes in the slipstream. This work was undertaken November 5, 1951, and satisfactory hardware was being produced 10 days later.

The Mk 8 Mod 0 weapon was initially produced in November 1951 and was stockpiled in January 1952.

(b)(1), (b)(3)

The Military Liaison Committee, in a letter dated October 20, 1952, requested that the bomb be designed to withstand storage for 6-month periods under occasional temperature extremes of -80°F to +165°F, and flight bomb-bay temperatures of -90°F. It was pointed out that external bomb carriage might experience even more rigorous conditions of -100°F during a 12-hour flight, and that the 24-hour limitation regarding weapon assembly would be operationally troublesome.[40]

Inasmuch as the propellant characteristics were specified by the Bureau of Ordnance, the problem was referred to this organization.[41] It was noted that the environmental criteria had been specified after detail design of the Mk 8 had been essentially completed, and that these criteria differed considerably from the initial Mk 8 development objectives. It was also pointed out that any project to provide a propellant with improved temperature characteristics would duplicate work being undertaken in the TX-11 program. The Bureau of Ordnance subsequently allowed relaxation of the temperature limitations to 7 days at 130°F, 60 days at 120°F, and indefinitely at 110°F.[42] On March 12, 1953, the Military Liaison Committee agreed that major redesign efforts toward relieving temperature limits be directed toward the TX-11.[43]

The possibility of water leakage into the interior of the gun nuclear system had been a matter of early concern.

(b)(1), (b)(3)

When recovered, there was only about half a cup of water in the barrel, and this leakage was not felt great. Nevertheless, the Military, in the April 16, 1952 meeting of the Sandia Weapons Development Board, requested that the possible effects of this leakage on weapon performance be studied.[38]

Consequently, drops were made on a limestone bed in southwestern New Mexico. This rock possessed extremely high compressive strengths, from 18,000 to 23,000 pounds per square inch (average concrete strengths were about 4500 psi).

(b)(1), (b)(3)

Only one weapon showed any evidence of leakage. Experiments were started, using O-rings as replacements for the cork gaskets used to seal the openings in the bomb case.

It had been decided that the TX-8-X2 changes constituted a modification to the fuze rather than the bomb. Thus the Mk 8 Bomb with Mk 8 Mod 1 Fuze, incorporating a frangible nose and T-31 fuze tape control, was released for production and entered stockpile September 1953.

The TX-G Committee, whose functions had been largely assumed by the Special Weapons Development Board, was dissolved in January 1954. The Aspen Committee, which was directing Sandia-Los Alamos activities on the TX-11 weapon, agreed to handle any residual interlaboratory matters on the Mk 8 program.

(b)(3)

This change was made in the Mk 8 Mod 2 Bomb which was stockpiled in May 1955.

Meanwhile, studies had been made of the desirability of replacing the original Abner initiator with an improved design, the Phoebe. This change, plus the O-rings for sealing the bomb case, was known as the TX-8-X3 program during development.[44] Changes to the Atomic Energy Act permitted the Military to produce and stockpile certain atomic weapons parts, and it was suggested that the Bureau of Ordnance assume control of TX-8-X3 production work.[45] This proposal was rejected by the Atomic Energy Commission, which felt that close phasing was required, due to changes to both nuclear and nonnuclear portions of the Mk 8, and that Sandia should retain production control.[46] The Mk 8 Mod 3 was stockpiled in October 1955.

By February 1957, the Mk 11 Bomb was in production and entering stockpile. A decision was made to retire the Mk 8 weapons on a one-for-one basis as Mk 11's entered War Reserve. This retirement program started May 1957 and was completed 2 months later.

Mk 8 Warhead

The first consideration of a gun-type device for use with guided missiles was in a Los Alamos meeting of early March 1950, in which various missile programs were discussed.[47] Little immediate action was taken and, during the summer of that year, attention was concentrated on developing the Elsie as a free-fall bomb to be released from aircraft. However, September 13, 1950, Santa Fe Operations Office requested Sandia and Los Alamos to consider the application of a penetrating warhead to various guided missiles. The missiles suggested were the HERMES A-3, HERMES C-1, REGULUS, RIGEL, and TRITON.[48]

It was obvious that a gun-type warhead would be more impact-resistant than an implosion design, and the request was referred to the Bureau of Ordnance, then doing work on the Mk 8 Bomb.

(b)(1), (b)(3)

Any missile usage would involve higher impact velocities and require new tests and additional design effort.[49] The Division of Military Application then referred the project to the Sandia Weapons Development Board, requesting that any Mk 8 Warhead developed be compatible with the above five missiles.[50]

Sandia made a preliminary study and, December 20, 1950, reported to the Santa Fe Operations Office that a firm estimate of the magnitude of the program could not be made. The terminal velocities of the missiles cited had not been definitely fixed, but were believed to be significantly greater than any previously considered in atomic-bomb design. Sandia proposed that a general investigation of impact warheads be continued, in an effort to delineate the most universally useful type of warhead and to outline a development program.[51]

The Santa Fe Operations Office suggested that initial application of the penetrating warhead be made to the REGULUS missile. This missile, scheduled for production in 1953, had a comparatively low impact velocity, and it was felt that a suitable warhead might be created by relatively simple modifications of existing components.[52] Sandia reported, January 23, 1951, that the development of such a warhead appeared feasible, and that the Bureau of Ordnance had been requested to investigate the effects of impact velocities and warhead mounting methods on the penetration characteristics of the Mk 8 device.[53]

The XW-8/REGULUS was authorized for design activity by the Santa Fe Operations Office February 14, 1951.[54] It was noted that since the REGULUS would attain an impact velocity of only Mach 1.2, there would be few shock problems, unless the weapon were employed against extremely hard targets such as igneous rock or heavy armor plate.[55]

It was determined that the fuzing accuracy for the XW-8/REGULUS could be less than for an air-burst device, since the only requirement was to initiate a pyrotechnic delay train about one minute prior to impact. Should the weapon be launched from a submarine, a simple arming system would protect the submarine against premature detonations.

The Sandia Weapons Development Board discussed the Mk 8 missile-warhead program in its April 10, 1951 meeting. It was felt that current weapon capabilities would not allow impact velocities higher than Mach 2.5 without danger of breakup of the device. Since the terminal velocity of the HERMES was estimated to be Mach 4.5, it was obvious that radical changes to either warhead or missile would have to be made if this missile were used. It was apparent that either approach would require much design investigation, and it was decided to consider only the XW-8/REGULUS.[56]

It was found that the warhead compartment of the REGULUS was long enough to hold the basic Mk 8 Bomb assembly, but that little excess clearance was available, and that access to the nose of the weapon was difficult. Additionally, the center of gravity of the missile would be about 30 inches forward of its optimum location, and it was decided to delete the afterbody of the Mk 8. Tests were started to determine the terraballistics of the Mk 8 without its afterbody, and to ascertain whether the warhead would break away from the missile on impact with various surfaces.[57]

Another problem was the development of a mechanism to ignite the propellant of the internal gun device of the XW-8/REGULUS. In the drop bomb, this was accomplished by arming tapes, but the warhead application required either a device to pull the tapes at the proper point in the missile trajectory or a modification of the fuze.

yield would be the same as that of the Mk 8 Bomb. The warhead would function properly when subjected to missile impact speeds up to Mach 1.1 on water, earth, reinforced concrete and, if possible, harder targets. It would not broach or ricochet after impacts at angles between 60 and 90 degrees. The weapon would penetrate the target and detonate after coming to rest, and would be sufficiently watertight to function after water impact, followed by bottom impact.[64]

The Military Liaison Committee notified the Division of Military Application, October 3, 1952, that no requirement existed for design of penetration warheads capable of impact velocities higher than those of the REGULUS missile.[65]

Meanwhile, the Military decided that efficient use of the XW-8/REGULUS weapon required a high delivery accuracy. This was not possible with the existing missile system, and production requirements were deferred, awaiting refinement of the missile guidance system. Sandia was requested to complete its design work on the warhead, and the Navy was asked to proceed with scheduled flight tests.[66]

Successful component evaluation flights were conducted, and a successful warhead system test was held September 24, 1953. The Military Liaison Committee then suggested that, since there were few differences between the XW-8 Warhead and the extensively tested Mk 8 Bomb, further systems tests be held in abeyance.[67]

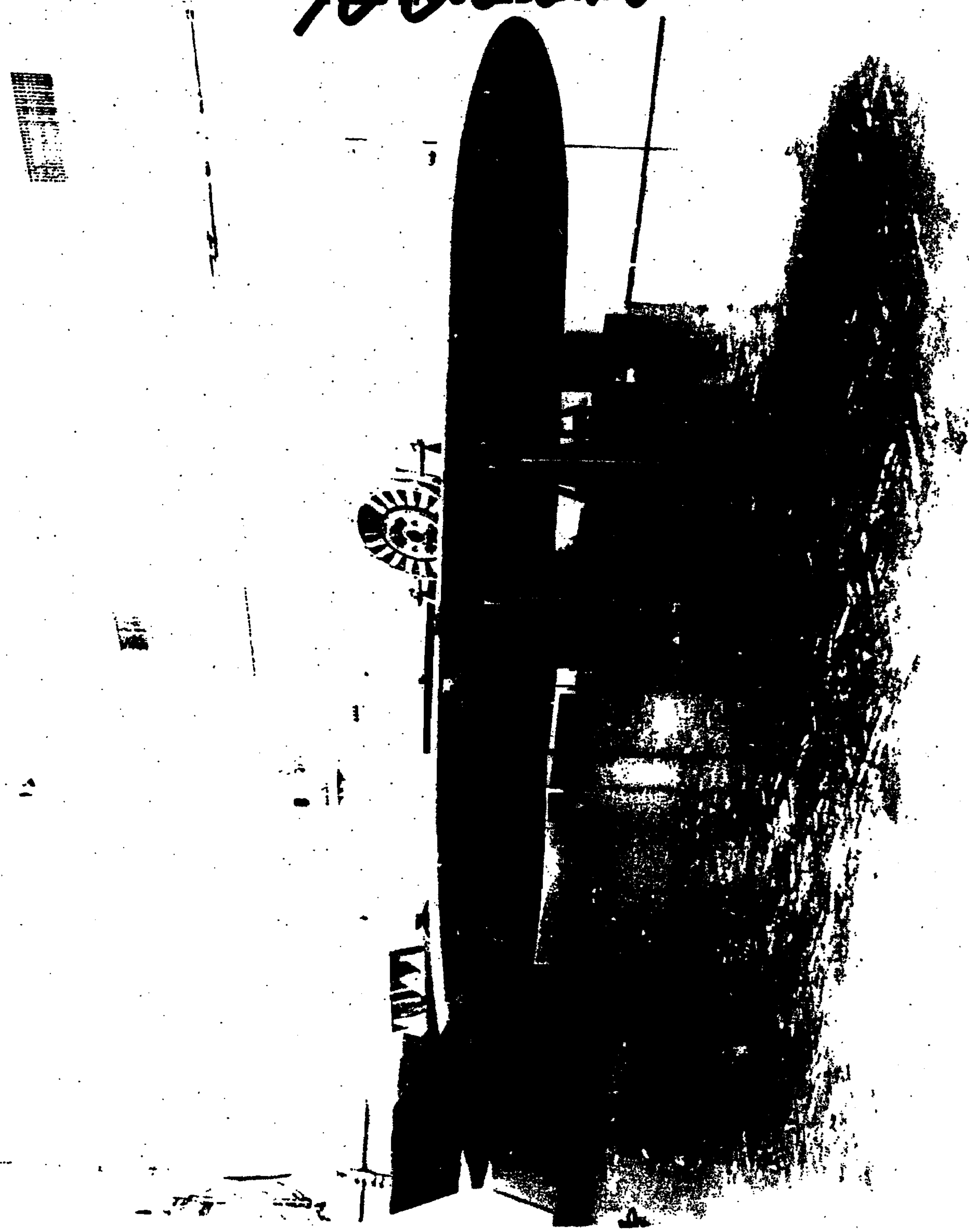
Design of the missile-warhead was completed in August 1954, and Report SC3483(TR), Status and Evaluation of the XW-8/REGULUS Warhead Installation at Design Release, was presented to the December 1, 1954 meeting of the Special Weapons Development Board.[68] The warhead was named the Mk 8 Mod 2, and production responsibility assigned to the Bureau of Ordnance.

The warhead contained three delay fuzes, two located on the side and one on the nose.

(b)(3)

All requirements of the military characteristics were satisfied by the test program, although impact tests at less than 90 degrees were not conducted, and it was not definitely determined whether the warhead would penetrate the target or break away on impact. However, Mk 8 Bomb tests had shown that satisfactory penetrations were achieved at entry angles as low as 30 degrees to the surface, and it was felt that the warhead would have similar satisfactory characteristics.

Subsequently, the possibility of developing a guidance system to effectively deliver the XW-8/REGULUS with pinpoint accuracy appeared remote. Consequently, on May 20, 1955, the Navy suspended activity in the program, together with work on the XW-11/REGULUS application.[69]



TX-10 External View

Subsequently, the Division of Military Application proposed that a lightweight, air-burst, gun-type missile warhead be developed,[74] and this suggestion received the backing of the Military Liaison Committee July 6, 1950.[75] It was proposed that Army Ordnance, then involved with the Mk 9 Shell, be requested to assist in design and development.[76]

Meanwhile, the lightweight, air-burst, gun-type bomb project had not been entirely forgotten, and the Military Liaison Committee, in a letter dated August 9, 1950, stated that the Joint Chiefs of Staff had established a requirement for the development of air-burst bombs sufficiently light in weight and small in cross section to be carried by high-speed tactical airplanes of the Air Force and Navy. It was felt that these bombs could be based on either implosion- or gun-type nuclear devices, and formal requests were made for both types.[77]

The subject was discussed in the August 16, 1950 meeting of the Sandia Weapons Development Board, with the Board agreeing to assume cognizance of the project. Two problems were immediately apparent: The development of a flexible fuzing system capable of attacking various tactical targets, and a weapon resistant to temperatures as low as -100°F.[78]

Sandia had meanwhile made a study of a lightweight bomb design and reported to AEC-Sandia August 17, 1950, that this could be produced by mid-1952. It was suggested that North American Aviation, Inc., be assigned the task of developing and manufacturing the outer case, internal support structures, and parts of the carrying pylon. Sandia would develop a fuzing and firing system, conduct drop tests, provide test and handling equipment, and act as project coordinator.[79]

On the same date, the Division of Military Application forwarded military characteristics for the above bomb. These required that the bomb be capable of tactical use by fighter, light bombardment, and attack (dive bomber) aircraft. The primary requirement was for external carriage, with alternate internal carriage being desired.

(b)(1), (b)(3)

The TX-G or Gun Committee agreed to accept interlaboratory responsibility for the TX-10.[26] The program was subjected to an intensive review in a Committee meeting of December 14, 1950, with the TX-10 being compared with the TX-7, an implosion design that had been pushed rapidly and which was now scheduled to enter stockpile earlier than the TX-10. It was felt by some conferees that the basic need for the TX-10 was eliminated by the advent of the TX-7. This latter weapon was larger than the proposed diameter of the TX-10 (27 inches versus 17 inches), but there appeared to be a sufficient variety of airplanes that could carry the TX-7.

(b)(1), (b)(3)

The problem was referred to the Sandia Weapons Development Board and discussed in a meeting December 20, 1950, with the Board being furnished copies of Sandia Report SC-1684(TR), A Critical Comparison Between the TX-7 and TX-10 Programs. This report noted that design was in work on a follow-on (and smaller) implosion device for the TX-7 (to be called the TX-12). The TX-12 would be less costly from the nuclear standpoint, would offer greater chances of increasing nuclear efficiency, and could be developed in about the same time scales. It was pointed out that work on the TX-10 would subtract effort from the TX-12, and that tactical use of the TX-10 (if manufactured in large numbers) would require major realignment of component production.

The Board noted that the TX-10 diameter would probably be smaller than the TX-7 or TX-12, but stated that further reductions in implosion-weapon diameter could be expected, as much nuclear design effort was currently being placed on implosion design improvements. After extensive discussion, the Board recommended that the TX-10 development be dropped in favor of the TX-12.[89]

The Division of Military Application wrote to Santa Fe Operations Office January 3, 1951, making reference to the above meeting. There were hopes that an interim TX-10 could be made available earlier than the TX-12, and it was suggested that the requirement for nuclear safing be eliminated and an external shape suitable for subsonic (but not necessarily supersonic) carriage be provided.[90]

The design status of the TX-10 was reviewed in the April 10, 1951 meeting of the Sandia Weapons Development Board. The bomb would be at least 17 inches in diameter and 2000 pounds in weight.

(b)(3), (b)(1)

The Board noted that the diameter and weight of the TX-10 exceeded the military characteristics, and that major reductions in these items could not be expected until the nuclear gun design was revised by Los Alamos.

(b)(3)

The project thus reverted to fundamental study of the problems of providing low burst heights, miniaturization, supersonic aerodynamics, and nuclear design improvements. Subsequently, the Military Liaison Committee canceled the TX-10 Bomb program May 7, 1952, noting that the Joint Chiefs of Staff had stated that a military requirement for the weapon no longer existed.

(b)(3)

(b)(1), (b)(3)

Mk 91 Mod 0 Bomb Cross Section

Mk 11 Weapon

The Mk 11 Bomb, a gun-type penetrating weapon to be externally carried on high-speed aircraft, had its early beginnings when the gun-type device was considered for guided-missile application in March 1950. In this usage nuclear safing would be required to protect the missile launching site, and it would be necessary for the warhead to survive high impact velocities.[47]

Subsequently, the Division of Military Application expressed interest in a gun-type bomb that could be nuclearly safed and externally carried on high-speed aircraft.[99] The external shape of the Mk 8 did not lend itself to such carriage (due chiefly to its blunt nose), and it was felt that any modification of the nose shape would be complicated by the existence of the nose fuze. A nose redesign would require a lengthy effort, and it was suggested that a development program be authorized for a Mk II Elsie for such usage.[100]

The Military Liaison Committee released a set of desired military and technical characteristics for impact, delayed-action atomic bombs April 17, 1950. These characteristics described a bomb which could be nuclearly safed during aircraft carriage and that would be suitable for release at speeds up to Mach 1.2.[54] Subsequently, July 31, 1950, the Division of Military Application requested the Bureau of Ordnance to design a Mk 8-type weapon meeting these characteristics, and offered Sandia assistance in the task of fitting the design to appropriate carrying aircraft.[101] This proposal was accepted by the Bureau of Ordnance,[102] and nomenclature of TX-11 was assigned to the project November 29, 1950.[103]

There were three main gun-weapon problems being studied at this time: The ballistics problem relating to external carriage and release at high speeds; the nuclear safing problem, which concerned missiles as well as bombs; and the problem of increasing the resistance of the weapon to impacts on hard targets, such as reinforced concrete, rock and armor plate.

The Naval Ordnance Laboratory started to design the TX-11 fuzing system. It was felt that feasibility and preliminary design studies to establish tentative characteristics could be completed by January 1, 1952; and that detailed design toss, glide and dive bombing. It would be capable of carriage and release at speeds up to Mach 1.4 and altitudes of 50,000 feet. It would be able to function satisfactorily after impacts on water, soil, reinforced concrete, and--to the extent practicable--harder targets.

The Board noted that the characteristics required external carriage at both subsonic and supersonic speeds, but a shape designed for one of these velocities would not be optimum for the other. It was felt that the design should be based on the assumption that the least drag during the major portion of the flight was desirable. Inasmuch as jet fighters en route to a target cruised at subsonic speeds, the bomb shape should be designed to meet this requirement.

The desire that the weapon be capable of penetration into hard rock was of concern. It was difficult to suitably define "hard rock," and there was felt to be a low incidence of this type of terrain near any probable targets. The scheduled design-release date was established as October 1953, with the bomb to enter stockpile in January 1955.[34]

The Bureau of Ordnance had been conducting tests of a soft-steel nose cap which, it was hoped, would crush and absorb the shock of weapon impact. These tests were not encouraging, and it was eventually decided to provide a Fiberglas nose cap. When the bomb was to be carried in an internal bomb bay, this nose cap could be removed.

Wind-tunnel tests had meanwhile narrowed the choice of weapon length to two possibilities; 146 and 169 inches. The Bureau of Ordnance recommended that the shorter figure be selected: It caused less drag at subsonic speed, it was compatible with all aircraft being considered for carriage of the bomb, and it could be carried internally in all aircraft except the B-50 without removing the nose cap.[109]

Full-scale drops at Inyokern produced excellent results.

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No detonation of the high explosive occurred during any of the impacts. Tests of 6-1/4-inch-diameter scale models against reinforced concrete 10 feet thick demonstrated that impact velocities between 2000 and 2200 feet per second could be absorbed.[110] As a result of these tests, the length of the TX-11 was frozen at 146 inches on June 30, 1952, and the fin size was established at two bomb diameters, or 28 inches.[111]

Meanwhile, work had been undertaken on the design of a nuclear safing system,

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The fuzes were mechanically armed and were of a pyrotechnic design similar to those used in the Mk 8.

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Glossary of Terms

Ad Hoc Working Group -- A group established by the Guided Missiles Committee to oversee the design of one particular missile-warhead installation.

Armed Forces Special Weapons Project -- An interdepartmental agency formed to handle military functions related to atomic weapons.

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Contact Fuze -- A fuze that detonates the weapon by contact with the ground or target.

Crossroads -- Full-scale tests of Mk III Bombs, held at the Pacific Proving Grounds. The Bikini Baker shot was held July 25, 1946. Much effects data were gained, and the shot was so destructive that a scheduled deep underwater burst was canceled.

Division of Military Application -- An AEC office that functions as liaison between the Military and weapons designers and producers.

Drag -- Resistance created by the passage of a shape through the air.

Field Command -- The local office of the Armed Forces Special Weapons Project, located on Sandia Base, Albuquerque, New Mexico.

Joint Research and Development Board -- A Board established in mid-1946 as a postwar replacement for the Office of Scientific Research and Development. Its purpose was to suggest lines of research and development on military weapons and equipment.

Kiloton -- A means of measuring the yield of an atomic device by comparing its output with the effect of an explosion of TNT. A 1-kiloton yield is equivalent to the detonation effect of 1000 tons of high explosive.

Little Boy -- Code name for the gun-type weapon dropped on Hiroshima, Japan, August 6, 1945, during World War II. Originally called the Thin Man in reference to its long thin shape. The Thin Man was to use plutonium-239 as its nuclear material. Early samples of this isotope revealed that it contained small amounts of plutonium-240 which had a high preinitiation rate. A decision was then made to use uranium-235, allowing the length of the weapon to be radically reduced (due to the lower speed of assembly of the critical material). This change in outer shape was given the code name of Little Boy.

Los Alamos Scientific Laboratory -- A nuclear design organization located at Los Alamos, New Mexico. Called the Los Alamos Laboratory during World War II.

Mach -- A measure of speed. Mach 1.0 is the speed of sound, or 738 miles per hour at sea level.

Manhattan Engineer District -- A District of the Army Engineers established in August 1942 to provide the facilities that would be needed for design and construction of the atomic bomb.

Military Characteristics -- The attributes of a weapon that are desired by the Military.

Military Liaison Committee -- A Department of Defense committee established by the Atomic Energy Act to advise and consult with the AEC on all matters relating to military applications of atomic energy.

Naval Ordnance Laboratory -- A portion of the Bureau of Ordnance devoted to design and test of Naval ordnance.

Neutron -- An uncharged particle of slightly greater mass than the proton.

Operation Crossroads -- See Crossroads.

Pitch -- Motion of the bomb as it falls through the air, such that the nose and tail alternately rise and fall.

Proton -- The nucleus of the atom of the light isotope of hydrogen. It has a unit positive charge of electricity.

Prototype -- An early weapon type, generally hand-produced before a production run.

Pylon -- A strut to hold bomb in position below an airplane wing.

Pyrotechnic Fuze -- A fuze that operates by burning or detonation of a small charge of explosive.

Radar -- Named for Radio Detecting and Ranging. Radars emit a pulse of high-frequency energy and measure the time lapse from that transmission to receipt of a reflected electrical "echo" from an object. This time measurement determines the distance of the object from the transmitting antenna of the radar.

Ricochet -- A glancing rebound of a missile when it strikes a target.

Safing -- Putting a weapon in condition such that it cannot fire.

Salton Sea Test Base -- Located on the site of a Naval Auxiliary Air Station on the shores of Salton Sea, California. One of the early sites for ballistic tests of atomic bombs.

Sandia Research and Development Board -- A joint Sandia-Military board formed March 2, 1948, at Sandia Base to provide local guidance on weapons design.

<u>Uranium-238</u> -- A radioactive element, atomic number 92. Natural uranium contains about 99.3-percent of uranium-238; the rest is uranium-235.

<u>Z Division</u> -- A division of the Los Alamos Scientific Laboratory, elements of which moved to Sandia Base and became the nucleus of Sandia Laboratory and Corporation.

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RS 3434/7

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RS 3434/8

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MK 33 (T-317)
8" SHELL

TOTAL WT. ~~243 LBS.~~

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Mk 33 Shell Cross-Section

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Mk 23 Shell

12/28/53	Military Liaison Committee forwards development requirement for 16-inch Navy projectile (Katie) to Division of Military Application.
11/1/54	Military characteristics proposed.
7/1/55	Military Liaison Committee approves military characteristics.
10/56	Mk 23 Shell stockpiled.

TX-32 Shell

5/5/54	Division of Military Application requests Santa Fe Operations Office to develop a 240-mm atomic shell.
6/18/54	Division of Military Application releases military characteristics for T332 Shell.
5/55	Project canceled in favor of XW-48 implosion program.

Mk 33 Shell

6-53	Army Ordnance authorizes development of T317 8-inch atomic projectile.
2/54	Development funds for project provided.
4/54	Program placed on crash basis.
2/55	Emergency capability production achieved.

History of Gun-Type Artillery-Fired Atomic Projectiles

Mk 9 Shell

The possibility of developing an artillery-delivered gun-type atomic device was discussed in late 1949 by Army Ordnance. This shell would be a defensive or offensive weapon against infantry masses concentrated in front of the sector through which a breakthrough was planned. It was hoped that a nuclear artillery shell, fuzed for air burst, could destroy the ability of these troops to stage an attack, or to defend the sector.

Possible delivery methods considered for such a weapon included railway rifles, guided missiles, aircraft, or artillery field pieces. Railway rifles, besides being almost obsolete, were ruled out due to heavy weight and relative immobility. Guided missiles capable of carrying atomic warheads were not as yet available. Bombing inaccuracy and difficulty in identifying battlefield targets made use of aircraft-delivered weapons unattractive.

It was felt, however, that artillery field pieces could be used, at least until suitable guided missiles became available. Army Ordnance had developed a mobile gun of 240-mm diameter (about 9-1/2 inches), weighing 90 tons, which was soon to be proof-fired, and a conference was held with Los Alamos Scientific Laboratory personnel November 10, 1949, at which use of this gun was advocated. The nuclear designers stated that a gun-type nuclear device would fit inside a 240-mm gun barrel, although concern was felt about the relatively inefficient usage of fissionable material in such an assembly.[1]

Another meeting was held on the same subject January 16-17, 1950. Increased Los Alamos interest in the project had developed, and Army Ordnance representatives discussed possible shell designs. One proposal was to develop a 240-mm-diameter shell, to fit the mobile gun, and another was to install a 280-mm barrel on the 240-mm mount, thus allowing the shell diameter to increase to about 11 inches.[2]

AFAP (Artillery-Fired Atomic Projectile), and Button (possibly because it was predicted that the shell could be delivered "right on the button").

The Ordnance Department proposed a set of military characteristics that were considered in a Button Committee meeting of August 11, 1950, and accepted on a preliminary basis.[9] The shell would weigh about 890 pounds and be fired with a muzzle velocity of 1700 feet per second from a 280-mm gun mounted on a 240-mm carriage.

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The shell would be able to withstand temperatures from -65°F to +160°F during storage and transportation, and operating-temperature limitations would be determined by the gun itself.[10]

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A device would be designed to provide a surface burst, and it was hoped that this feature could be available concurrently with the time fuze.

The Button Coordination Committee was dissolved October 23, 1950, with Santa Fe Operations Office noting that the number and variety of weapons currently being developed necessitated the establishment of a uniform policy for assignment of responsibilities. Button was in full development but not yet scheduled for production, and Los Alamos and Sandia were requested to assume normal project responsibilities.[12] Subsequently, Sandia took over control of the nonnuclear phases of Button, and reassigned many of the design tasks to Army Ordnance.

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However, subsequent design improvements, selection of high-quality component parts, and eventually, the use of three parallel fuzes, increased operational reliability to the point where timer fuzes were felt to be satisfactory.

Prototype shells were being fired by mid-1951, and demonstrated that nuclear assembly was taking place at the proper point in the trajectory.

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This created a maximum force of 3800 g's. The design of a lighter version with longer range was considered, but the higher stresses involved in this design caused later abandonment of this modification.

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A proposed TX-9 status and characteristics report was prepared by the TX-G Committee. This noted that development of the TX-9 had been telescoped to such an extent that much of the testing would have to be conducted after the design had been released to production.

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Three independently operating mechanical time fuzes were located near the nose of the shell.

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The TX-G Committee met November 2, 1951, and noted that much TX-9 work remained to be done, including testing of the initiators, fuzes, and the conduct of a full-scale nuclear test; and that temperature limitations on both shell and gun were yet to be established. However, the stockpile date would not permit delaying design freeze. There had been no formal issuance of the military characteristics, but the Committee felt that the TX-9 design was adequate for operational use.[22] Design release was accordingly issued November 15, 1951.[23]

The Sandia Weapons Development Board, meeting January 16, 1952, recommended that the TX-9 be released "to" (rather than "for") production.[24] The choice of preposition indicated that the weapon, in some respects such as tests and drawings, was not at the normal stage of release for full production activity.[25] The weapon system was praised for its mobility, and it was noted that the gun could be emplaced in 15 minutes, and that the same length of time was required to assemble and fire the nuclear round.

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The Sandia Weapons Development Board, February 11, 1952, again recommended that the TX-9 be released to production,[26] and this was accepted by the Military Liaison Committee April 14, 1952.[27]

Initial deliveries of the TX-9 to stockpile were made in April 1952, right on schedule. Since the military characteristics had not been issued and the testing program was not completed, these units were temporarily designated as PM-9 or Pre-Mark, rather than by the more formal title of Mk 9 Mod 0.[28]

The military characteristics were officially released by the Military Liaison Committee July 18, 1952.[29]

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The shell would be able to withstand 100-percent humidity and temperatures up to 90°F.[30]

Sandia recommended to Santa Fe Operations Office October 14, 1952, that the Mk 9 Mod 0 Shell be approved for operational suitability, training, and emergency use, based on examination of 12 early-production shells from Picatinny Arsenal. This proposal was accepted, and the first War Reserve-quality shells, the Mk 9 Mod 0-ZZ, were accepted for stockpiling in October 1952 (ZZ was the nuclear identification).[31]

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The controllable arming feature of the military characteristics was given attention. The TX-G Committee took this under consideration, but later noted that it would be difficult to develop and might degrade the reliability of the shell due to its complexity.[34] The Committee reported that modification to the Mk 9 Mod 0, to bring it in line with all the military characteristics, would require much design and testing, and suggested that this work be assigned to the Ordnance Corps. It was felt that the need for TX-G Committee direction was declining, and that it could be replaced by an Ad Hoc Committee for each weapon. On December 15, 1952, the Atomic Energy Commission requested the Military Liaison Committee to transfer responsibility for nonnuclear components of the Mk 9 to the Army, but no action was taken.

The testing program required telemetering of internal events in the Mk 9 Shell, and this posed a difficult problem.

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Sandia had meanwhile concluded that a rugged and accurate telemetering system would be needed for rockets and guided missiles, and started to work on the problem.[36] This was a major undertaking, due to the 5000-g acceleration experienced by the shell. Additionally, the limited space available in the shell case demanded extreme circuit simplicity, and antenna design was severely restricted by the requirement that the external ballistic shape remain unchanged.

Both Army Ordnance and Sandia prepared designs of telemetering systems, and the results were evaluated in a TX-G Committee meeting September 18, 1952. The Ordnance system contained two channels with microsecond time resolution and four with millisecond time resolution. Sandia provided a dual system, each having five channels with microsecond and six with millisecond time resolution.

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The Picatinny system, being immediately available, was used for the first tests, and was later replaced by the Sandia system.[34]

The Sandia telemetering system was tested at Aberdeen in mid-December 1952. Results were generally satisfactory, but swampy terrain prohibited efficient location of telemetering receiving stations, and the range was too short for the maximum range of the Mk 9.[37] A proposal was made that the telemetering tests be conducted at the Nevada Test Site, but the location was later changed to Ft. Sill, Oklahoma, home of The Artillery Center. These tests were held from January 19, 1954, to February 5, 1954, with 19 rounds being fired. Telemetering results were excellent, as was the performance of the Mk 9 Shell.[38]

A full-scale test of the Mk 9 had meanwhile been proposed, both to provide the Army with an operational test and to allow effects studies, both nuclear and military.[39] A decision was made in late 1952 to conduct this test in Operation Upshot-Knothole at the Nevada Test Site,[40] and the Mk 9 Mod 0-ZZ Shell was successfully tested in Shot Grable May 23, 1953.

Some study had been given to updating the stockpiled PM-9's to Mark status. However, it was felt that the PM-9 was entirely adequate, and that conversion was not required. Production of the Mk 9 was completed November 1953.

In April 1957, the Mk 9 was replaced in stockpile by the Mk 19 Shell. Mk 9 Shells, tools, and test and handling equipment were transferred to the Army for training and test purposes.

Mk 19 Shell

By late 1952 it was felt possible to reduce the weight of the Mk 9 Shell by about 200 pounds. This would produce a shell with the same (280-mm or 11-inch) diameter as the Mk 9, but with longer range and higher yield. The proposed atomic projectile would have the same weight as conventional high-explosive 280-mm shells, making it unnecessary to provide special spotting rounds, firing tables, or propellant charges. The Army Ordnance Corps authorized this new project March 1953, and the design of this Shell, called by the Army the T315 or Button II, became the first item of business for the Acorn Committee, which was established April 2, 1953, to centralize work on gun-type weapons.

(b)(1), (b)(3)

The Division of Military Application authorized development of this program, called the TX-19 Shell, April 28, 1953.[42]

(b)(1), (b)(3)

Sandia entered the program in June 1954, when the Atomic Energy Commission requested it to provide inflight telemetry for the projectile firing tests.[45] Sandia developed a system by which the internal nuclear events, such as assembly of the subcritical portions of the gun, were monitored.

(b)(1), (b)(3)

The Shell would be 53.62 inches long, about an inch shorter than the Mk 9. The sequence of operation would be identical to the Mk 9, and the two shells would be externally very similar.

(b)(1), (b)(3)

The Army withdrew the requirement for controllable arming. New mechanical fuzes were developed, which were more easily set than those in the Mk 9. Tests were made of an impact device, to determine whether it was safe enough for use, but it did not become available in time.

Stockpiling of the nonnuclear parts of the new weapon started in July 1955.[46] Operational suitability tests were conducted in August 1955, and the Mk 19 was declared satisfactory for field use. (b)(1), (b)(3) The increased launching stresses due to the lighter weight required some redesign and strengthening of parts of the ignition, fuzing and safing systems.

The nose fuze and the two internal fuzes of the Mk 19 had redesigned setting features. Settings on the internal fuzes were made with a closed-end ratchet wrench that allowed more rapid and accurate positioning. All fuzes were set in a clockwise direction, facing the nose of the shell, to prevent backlash on firing.[44]

Mk 23 Shell

The development requirements for a 16-inch atomic projectile were forwarded by the Military Liaison Committee to the Division of Military Application December 28, 1953. These called for the design of a shell to be fired from Naval 16-inch rifles and which would use Mk 19 nuclear components.[47] The project, known as Katie, would develop a shell that could be used for atomic support during amphibious operations.

A design-release date of December 31, 1954, was proposed, with stockpiling by July 1955. The task was a relatively straightforward one; that of adapting the features of the 280-mm T315 (Mk 19) Shell to a case whose external configuration was that of the Navy 16-inch HC Projectile Mk 13.

(b)(1), (b)(3)

Nomenclature of TX-23 was assigned by Sandia March 30, 1954, and was Sandia's only involvement with the project, other than the work being accomplished on the Mk 19, which was also applicable to the Mk 23.[48]

(b)(1), (b)(3)

It was hoped to provide contact cleanup, but on a not-to-delay basis.[50]

The military characteristics were approved by the Military Liaison Committee in mid-1955. The fuzing system would be rugged, reliable, and easily set or reset.

(b)(1), (b)(3)

The shell would function in a temperature range from 0°F to 125°F, and preparation for firing would require no more than 15 minutes.[52] These characteristics were reviewed without comment by Sandia August 15, 1955.[53]

The status of the Mk 23 was discussed in the December 12, 1956 meeting of the Special Weapons Development Board. The shell had a diameter of 16 inches, a length of 63.7 inches, and a weight of 1900 pounds

(b)(1), (b)(3)

The fuzing system contained three independent mechanical time fuzes in the nose of the projectile.

(b)(1), (b)(3)

The Mk 23 was stockpiled, and initial units delivered to the Fleet in October 1956.[54] These initial deliveries were made during the same period that the Navy retired the last 16-inch rifle from active use.

TX-32 Shell

The Division of Military Application, May 5, 1954, requested the Santa Fe Operations Office to develop a 240-mm (~~8.65~~ 9.45 inch) atomic shell, using the Mk 9 gun-type nuclear components. This design would provide a shell for the Army's 240-mm howitzer. Full-scale development activities were subsequently authorized by the Santa Fe Operations Office, subject to availability of funds and to orderly integration of the project into the Los Alamos program.[55]

The Military characteristics for a Shell, AE, 240-mm, T332, were released by the Division of Military Application June 18, 1954. The Army would manage the project, and the Atomic Energy Commission would furnish nuclear design and components.[56]

(b)(1), (b)(3)

The design was canceled in May 1955, in favor of an 8-inch implosion design, the XW-48, which had been proposed by the University of California Radiation Laboratory.[58]

The design was made available July 1955, for emergency capability use with the 8-inch howitzer M-2.

(b)(1), (b)(3)

Glossary of Terms

(b)(1), (b)(3)

Field Command -- The local office of the Armed Forces Special Weapon Project, located on Sandia Base, Albuquerque, New Mexico.

g -- Force equal to one unit gravity.

Gun Committee -- A joint committee of Los Alamos Scientific Laboratory and Sandia members, established to guide the development of all gun-type weapons.

Gun-Type Design -- An atomic weapon based on the principle that a supercritical mass of nuclear material can be created by bringing together two subcritical masses of such material. In practice, this is accomplished by placing one of the subcritical masses at the end of a gun barrel and shooting the other subcritical mass into it.

Implosion -- The effect created when a sphere of high explosive provided with the appropriate lens charge to initiate the explosion is detonated on its exterior surface. The force of the shock wave is directed largely toward the center of the sphere.

Initiator -- A source of neutrons.

Joint Chiefs of Staff -- ~~An Army Navy Air Force group to~~ A group composed of the Chiefs of Staff of the Army, Navy and Air Force to determine policy and to develop joint strategic objectives of the Armed Forces.

Kiloton -- A means of measuring the yield of an atomic device by comparing its output with the effect of an explosion of TNT. A 1-kiloton yield is equivalent to the detonation effect of 1000 tons of high explosive.

Los Alamos Scientific Laboratory -- A nuclear design organization located at Los Alamos, New Mexico.

Mk 8 Bomb -- A gun-type atomic bomb and warhead designed for target penetration.

Microsecond -- One millionth of a second.

Military Characteristics -- The attributes of a weapon that are desired by the Military.

Military Liaison Committee -- A Department of Defense committee established by the Atomic Energy Act to advise and consult with the AEC on all matters relating to military applications of atomic energy.

Millisecond -- One thousandth of a second.

Operation Buster-Jangle -- See Buster-Jangle.

Operation Upshot-Knothole -- See Upshot-Knothole.

Oralloy -- A code term for enriched uranium. The two initial letters stand for Oak Ridge (where Oralloy was first made in quantity) added to alloy from Tube Alloys, Ltd., applied to the British wartime atomic energy project.

Picatinny Arsenal -- An arsenal of the Army, responsible for design of nuclear weapons for the Army.

Prototype -- An early weapon type, generally hand-produced before a production run.

Proximity Fuze -- A fuze that detonates the weapon as soon as it comes within a certain specified distance of the ground or target.

Sandia Weapons Development Board -- A joint Sandia-Military board at Sandia Base to provide local guidance on weapons design.

Santa Fe Operations Office -- The local office of the Atomic Energy Commission (AEC) concerned with Sandia operations.

Special Weapons Development Board -- Change of name for the Sandia Weapons Development Board, effective May 14, 1952.

Spotter Shells -- Nonnuclear shells that contain the same weight of projectile and powder charge as the atomic Shell. Can be used for proper range determination before the nuclear shell is fired.

(b)(1), (b)(3)

University of California Radiation Laboratory -- A laboratory established at Livermore, California. Initially founded for work on thermonuclear designs.

Upshot-Knothole -- Tests of atomic devices, held at the Nevada Test Site. Series of 11 shots, starting March 17 and ending June 4, 1953.

Uranium-235 -- A radioactive element, an isotope of uranium-238.

Uranium-238 -- A radioactive element, atomic number 92. Natural uranium contains about 99.3-percent of uranium-238; the rest is uranium-235.

Yield -- The measure of ~~A means of measuring~~ the effect of a nuclear detonation compared to ~~by comparing it with~~ the effect of an explosion of TNT. By definition one kiloton is 10^{12} calories.

14. SRD Ltr, Los Alamos Scientific Laboratory to Santa Fe Operations Office, dtd 12/8/50, subject, Scope of Ordnance Corps Work on Project Button. AEC Files, MRA-5, Mk 9, 9/50-12/50.

15.

(b)(3)

16. SRD Ltr, Sandia Corporation to Distribution, dtd 1/4/51, subject, TX-9 (Button) Progress Report--Fourth Quarter Calendar 1950. AEC Files, Mk 9, 1/51-3/51.

17. SRD Ltr, RS 1/123, Sandia Corporation to Santa Fe Operations Office, dtd 6/4/51, subject, TX-9 Development Program. SC Archives, microfilm reel MF-SF-SC-47.

18. SRD Ltr, Santa Fe Operations Office to Sandia Corporation, Los Alamos Scientific Laboratory and AEC-Sandia, dtd 6/15/51, subject, TX-9 and Mk 9 Scheduling. AEC Files, MRA, 9-1, TX-9, 4/51-7/51.

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(b)(3)

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22. SRD Minutes, RS 3466/60892, TX-G Committee to Distribution, dtd 11/2/51, subject, Minutes of 12th Meeting. SC Reports Files.

23. SRD Report, RS 1230/39, Sandia Corporation to Distribution, dtd 3/11/52, subject, Development Status, Mk 9 Weapon. AEC Files, MRA, Mk 9, 3/52-4/52.

24. SRD Minutes, RS 3466/60958, Sandia Weapons Development Board to Distribution, dtd 1/16/52, subject, Minutes of 59th Meeting. SC Archives, Transfer No. 48217.

25. SRD Ltr, RS 1/211, Sandia Corporation to Los Alamos Scientific Laboratory, dtd 1/9/52, subject, TX-9. Forms Appendix I to TX-G Steering Committee Minutes, 14th Meeting, 1/17/52, RS 3466/61369. SC Reports Files.

26. SRD Ltr, RS 1/228, Sandia Corporation to Division of Military Application, dtd 2/11/52. AEC Files, MRA, Mk 9, 2/52.

27. SRD Ltr, Military Liaison Committee to Division of Military Application, dtd 4/14/52, subject, Release to Production TX-9. AEC Files, 9-1, TX-9, 4/52-5/52.

28. SRD Ltr, Santa Fe Operations Office to Division of Military Application, dtd 6/19/52, subject, Stockpile Entry of TX-9 Weapon. Forms Appendix II to TX-G Steering Committee Minutes, 6/19/52. SC Reports Files.

29. SRD Ltr, Military Liaison Committee to Division of Military Application, dtd 7/18/52, subject, Military Characteristics for Shell, 280-mm, Atomic. SC Archives, Mk 9, Transfer No. 31366-7.

30. SRD Ltr, Santa Fe Operations Office to Los Alamos Scientific Laboratory and Sandia Corporation, dtd 8/15/52. SC Archives, TX-9, 1-9, Transfer No. 29891.

31. SRD Ltr, Santa Fe Operations Office to Division of Military Application, dtd 10/30/52, subject, First Approval of Mk 9 Mod 0 Weapon for Operational Suitability, Training and Emergency Use. AEC Files, MRA, Mk 9. 1/52-12/52.

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34. SRD Minutes, RS 3466/67384, TX-G Steering Committee to Distribution, dtd 9/18/52, subject, Minutes of 21st Meeting. SC Reports Files.

35.

(b)(3)

36. SRD Ltr, RS 5000/22, Sandia Corporation to Santa Fe Operations Office, dtd 5/29/52, subject, Tests of the TX-9 Telemetering System. AEC Files, MRA, Mk 9, 5/52-6/52.

37. SRD Ltr, RS 1/411, Sandia Corporation to Field Command, dtd 12/15/52, subject, Firing of Mk 9 Telemetering Test Round. AEC Files, MRA, Mk 9, 1/52-12/52.

38. SRD Report, RS 5222/28, Division 5222 to Distribution, dtd 3/11/54, subject, Operational Field Notes on Test of Mk 9 Weapon at Fort Sill, Oklahoma. SC Archives, TX-9, 3-1, 1953-4, Transfer No. 29890.

39. SRD Ltr, RS 1/317, Sandia Corporation to Santa Fe Operations Office, dtd 7/8/52, subject, Full Scale Test of the Atomic Shell. AEC Files, MRA, Mk 9, 1/52-12/52.

40. SRD Ltr, U. S. Atomic Energy Commission to Secretary of Defense, dtd 11/17/52. AEC Files, MRA, Mk 9, 1/52-12/52.

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(b)(3)

42. SRD Ltr, Santa Fe Operations Office to Los Alamos Scientific Laboratory, dtd 5/5/53, subject, 280-mm Atomic Shell with Longer Range. AEC Files, MRA, 9-1, TX-9, 4/54.

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(b)(3)

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45. SRD Ltr, AEC-Sandia to Sandia Corporation, dtd 6/18/54, subject, Request for Feasibility Study. AEC Files, MRA-5.

46.

(b)(3)

47.

48. SRD Ltr, RS 1000/1526, Sandia Corporation to AEC-Sandia, dtd 3/30/54, subject, Assignment of TX-23 Designation. AEC Files, MRA-5, Mk 23.

49.

(b)(1), (b)(3)

50. SRD Report, TX-N Committee to Distribution, dtd 11/8/54, subject, Guided Missiles Status Report. SC Central Technical Files, C-6.

51.

(b)(1), (b)(3)

52. SRD Ltr, RS 3466/87562, Santa Fe Operations Office to Sandia Corporation, dtd 7/11/55, subject, Military Characteristics of the 16-Inch Projectile Mk 23 Mod 0. SC Archives, M23 and TX-23.

53. SRD Ltr, RS 1300/509, Sandia Corporation to Santa Fe Operations Office, dtd 8/15/55, subject, Military Characteristics for the 16-Inch Projectile Mk 23 Mod 0. AEC Files, MRA-5, Mk 23.

54. SRD Minutes, RS 3466/82347, Special Weapons Development Board to Distribution, dtd 12/12/56, subject, Minutes of 104th Meeting, Part I. SC Archives, Transfer No. 48217.

55. SRD Ltr, RS 3466/139318, Santa Fe Operations Office to Los Alamos Scientific Laboratory, dtd 5/24/54, subject, Development Program for 240-mm Atomic Shell. SC Archives, Mk 9, Transfer No. 31366-7.

56. SRD Ltr, RS 3466/139320, Division of Military Application to Santa Fe Operations Office, dtd 6/18/54, subject, Military Characteristics for 240-mm Atomic Shell. SC Archives, Mk 9, Transfer No. 31366-7.

57.

(b)(3)

58. SRD Ltr, RS 3466/72885, Military Liaison Committee to U. S. Atomic Energy Commission, dtd 9/9/55, subject, Suspension of 240-mm Shell Program. SC Central Technical Files, TX-32, 1955.

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